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LANDSAT 4 PROGRAM

Progress report on the U.K. SATMaP program (F-01).

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Introduction

The following progress report describes the analysis of data from test tapes from the Unites States (specifically the August Arkansas scene), and the first tape of the UK which has been made available by ESRIN in Frascati. Due to various technical problems associated with Landsat 4 and TDRSS we have not yet received any data of our test sites from NASA as yet. A second scene of the UK containing our principal test sites has recently been sent to us by ESRIN, and results from this data set will be provided in our next progress report. As a consequence of these unavoidable problems, we have progressed less far with our work programme than anticipated originally, but nevertheless feel that the results presented here will be of substantial interest to NASA. It is to be hoped that the launch of Landsat D' will provide us with the data, necessary for the completion of our programme of work.

In the first section we discuss the methods for estimating spatial resolution and also give some preliminary results. In the second we discuss the characteristics of the data received from ESRIN and in the third the utility of various spectral bands of the Thematic Mapper for land cover mapping are outlined.

Estimation of spatial resolution

The resolution of the Thematic Mapper is specified as being 30 metres. This value is the spatial resolution corresponding to a modulation transfer factor of 0.35. In conventional optical terms, the value should be 70 metres since this is the corresponding full wave value, and the value of 30 metres is thus the half wave value. We describe below the procedure used to estimate the extent to which this value is achieved by analysis of edges on TM images.

Firstly it is worth commenting on the physical meaning of the values specified above. In photographic terms it is possible readily to understand the significance of the MTF values. In simple terms it means that the contrast between a series of bar targets will be reduced to 0.35 of their true contrast when the targets are 30 metres across and 30 metres apart. In the case of scanners, one also has to take account of the fact that the targets are not continuously scanned but are sampled. The resultant data have a pixel size of 30 metres as a result of thus sampling and subsequent processing. (P tapes have, of course,a pixel size of 28.5 metres as a result of resampling.) Thus if we consider the theoretical possibility of a series of real ground bar targets with 30 metre width and spacing, the resultant images of these bars will very probably not have a contrast of 0.35 of the original contrast. Indeed if the sampling by the scanner takes place across the boundaries between the targets and their background, then they may be undetectable. On the other hand, if the sampling takes place centrally within each target and the ground between then a contrast reduction of 0.35 may be found and the bars will be readily recognisable.

Intermediate locations will result in contrast ratios between 0 and 0.35 presumably, though depending on the orientation of the bar targets, various aliasing effects are likely to result.

In estimating the spatial resolution it is important that these considerations are kept in mind as shown below. In the conventional procedure for estimating spatial resolution from the images themselves, the first stage is to locate edges within the image, and extract the values along a line at right angles to the edge. With photographic imagery the normal method is to use a microdensitometer to obtain these values. The derivative of this edge is then obtained and a line-spread function is thereby produced. The fourier transform of the latter yields the modulation transfer function, which is the modulation transfer factor (loosely the contrast reduction) as function of spatial frequency. In practice various smoothing filters are used on the original edge and line spread function, and averages of several edges derived to provide an accurate estimate. If one applies this procedure to scanner data digital values, the resultant curve inevitably yields values very much greater than the 30 metres corresponding to the 0.35 modulation transfer factor, for the reasons described previously. Indeed it is impossible to obtain a spatial frequency corresponding to 30 metres, with a sampling interval of 30 metres whatever the steepness of the line spread function.

The above considerations mean that one has somehow to obtain fractional pixel values. Most analysis of Landsat 1 images relied on the use of photographic products when sampling at arbitrarily fine rates can be achieved. The problem with this method is that degrading photographic effects are being included as well the modulation transfer function of the microdensitometer. Instead we have used edges oblique to the down track direction to obtain the fractional

values. Details of the procedure used are as follows.

Firstly suitable edges are located on an image. This in itself is proving no easy task, since they must have the following properties.

i) they must be straight so that the relative position of the pixel lines can be accurately determined.

ii) they must be homogeneous on both sides of the edge.

iii) there must be no sub-pixel sized features (e.g. a ditch) along the edge.

These requirements eliminate the vast majority of edges found within a scene. Once a suitable edge has been found its orientation relative to the scan lines must be determined. Currently we do this interactively using a microbased image processing system. Having found this angle, the position of the lines relative to each other can be determined. The assumption is then made that the different lines represent the same target being imaged several times, but with the sampling of the scanner and hence position of the pixels relative to the edge being different on each line. In this way the spectral response of the edge can be determined with sub-pixel accuracy.

Figures 1,2 and 3 show the results of carrying out this procedure on one of the edges we have examined. At present we have only just started to obtain values of spatial resolution, and we regard these as tentative, since especially in the case of the values derived from the Arkansas scene we have no detailed ground knowledge of the edges, and only when we analyse the data from our test sites will we hope to present firm values. Nevertheless the results obtained so far are extremely encouraging. Using band 4 only since it is least affected by atmospheric interference, we have obtained estimates for the MTF value at 0.35 of 27.33, 30.3, 30.8 and 39.9 metres, the latter rather higher value being from the Arkansas image. Averaging in the frequency domain yields a value of 31.66 metres. Whether this rather close agreement with the expected value is a matter of

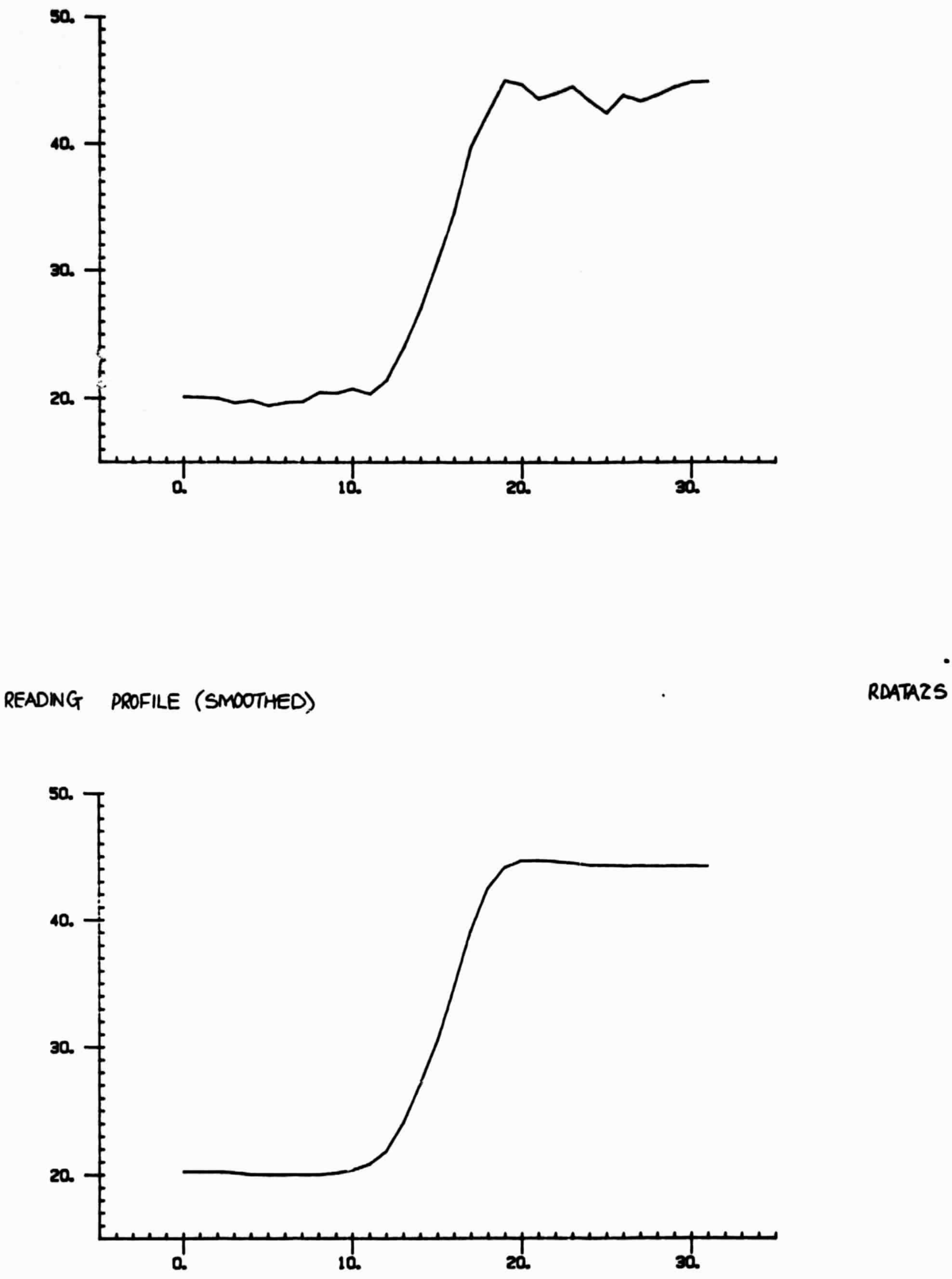

Figure 1 Original and smoothed edge from the UK Thematic Mapper scene.

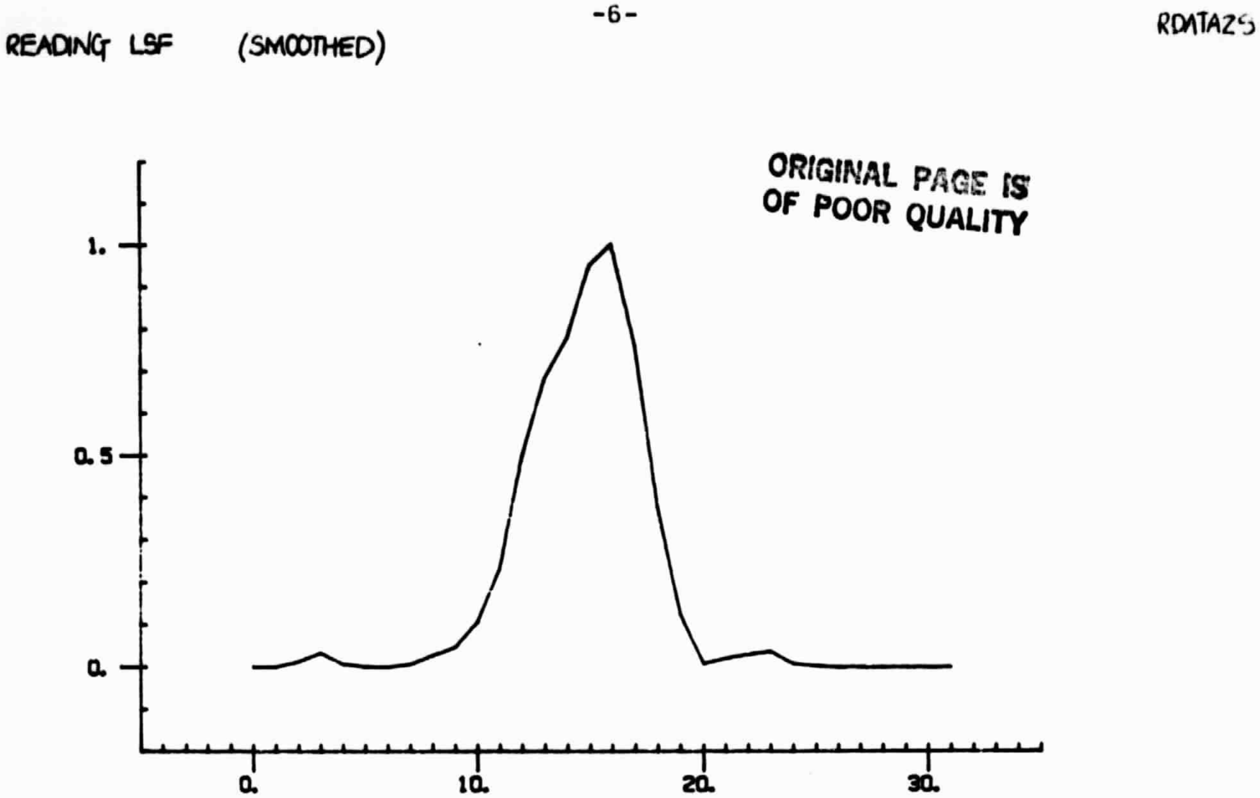

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Figure 2 Line spread function derived from the data shown in figure 1. The horizontal units are in 1/5th pixels.

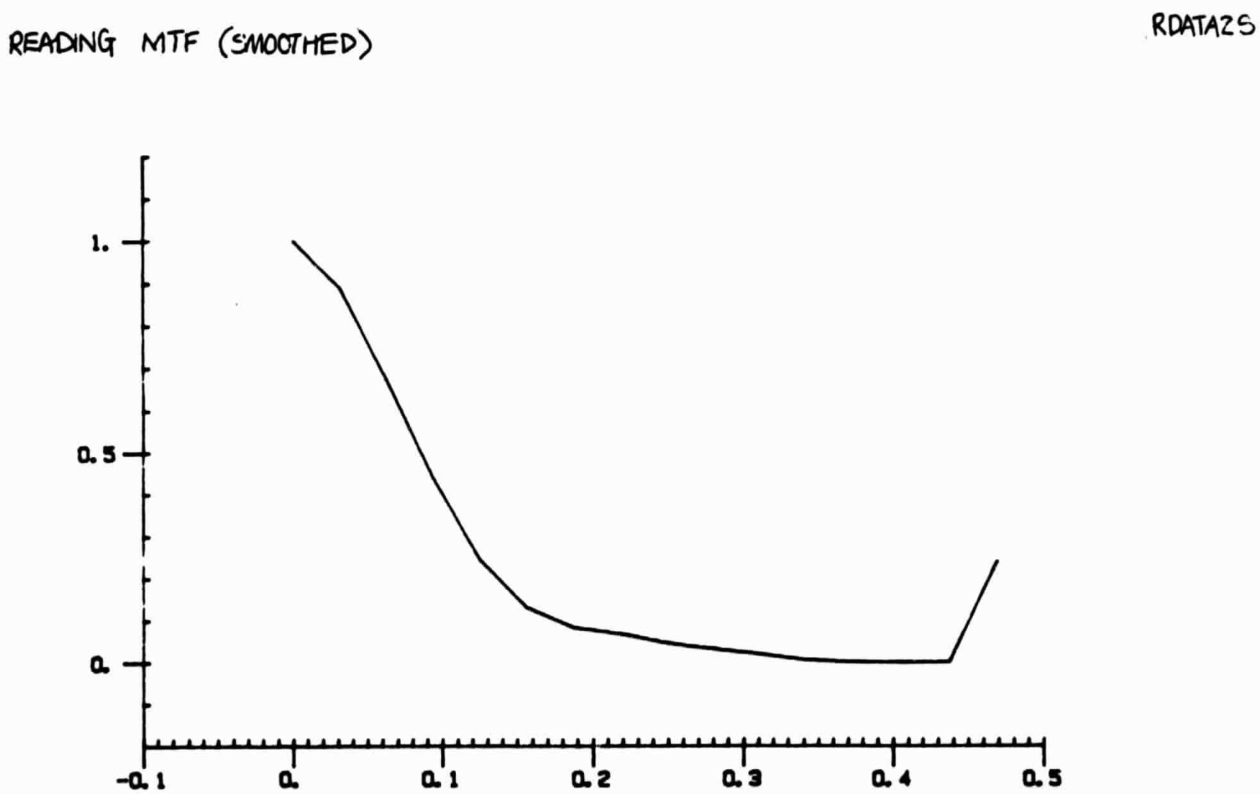

Figure 3 Resultant modulation transfer function derived by fourier transform of the data in figure 3.

serendipity or not, must await the analysis of many more edges. This work will now be carried out on the recently received image of our test sites in Eastern England.

Preliminary work has been carried out on the effective resolution element and on minimum classifiable area but there are no results to date to report.

Characteristics of the 1st UK scene from ESA/ESRIN Frascati.

We received in late July the first seven band image of the UK. It was received at the Fucino receiving station on the 3rd February 1983. Preliminary analysis of this image was performed at NASA/GSFC on the LAS. Subsequent work has been performed on the I^2S system of the NERC in Swindon UK.

The image corresponds apparently roughly to the B tapes supplied by NASA. The main apparent difference is that the ESRIN tape has had a nominal 46 pixel shift between adjacent scans. This removes a substantial proportion of the shifts present in B and A data, but nevertheless there are still substantial shifts left, due to small satellite movements. An example of such an image is shown in our first progress report. In this image a number of low pixel values were found scattered throughout the image. These are not present in the full seven band scene discussed here.

Figure 4 shows the histograms for the whole UK scene. As we have previously noted for the American data we have analysed, a relatively small proportion of the digital values are occupied. Moreover if we compare figure 5 which is of 512 by 512 subscene of the Arkansas data we see that for bands four five six and seven we see that the UK scene has an much narrower range. This could be a result of the relatively low illumination levels for the UK scene, or possibly a result of very different cover types in the two scenes. With reference to the latter it is worth pointing out that at this time of year the UK in the south does have many fields with a continuous cover of winter crops so that relatively high near IR (band 4) values would be expected, and the scene also contains water giving very low values. A third possibility is that differences in processing at ESRIN and GSFC may account for the contrasts between the two scenes.

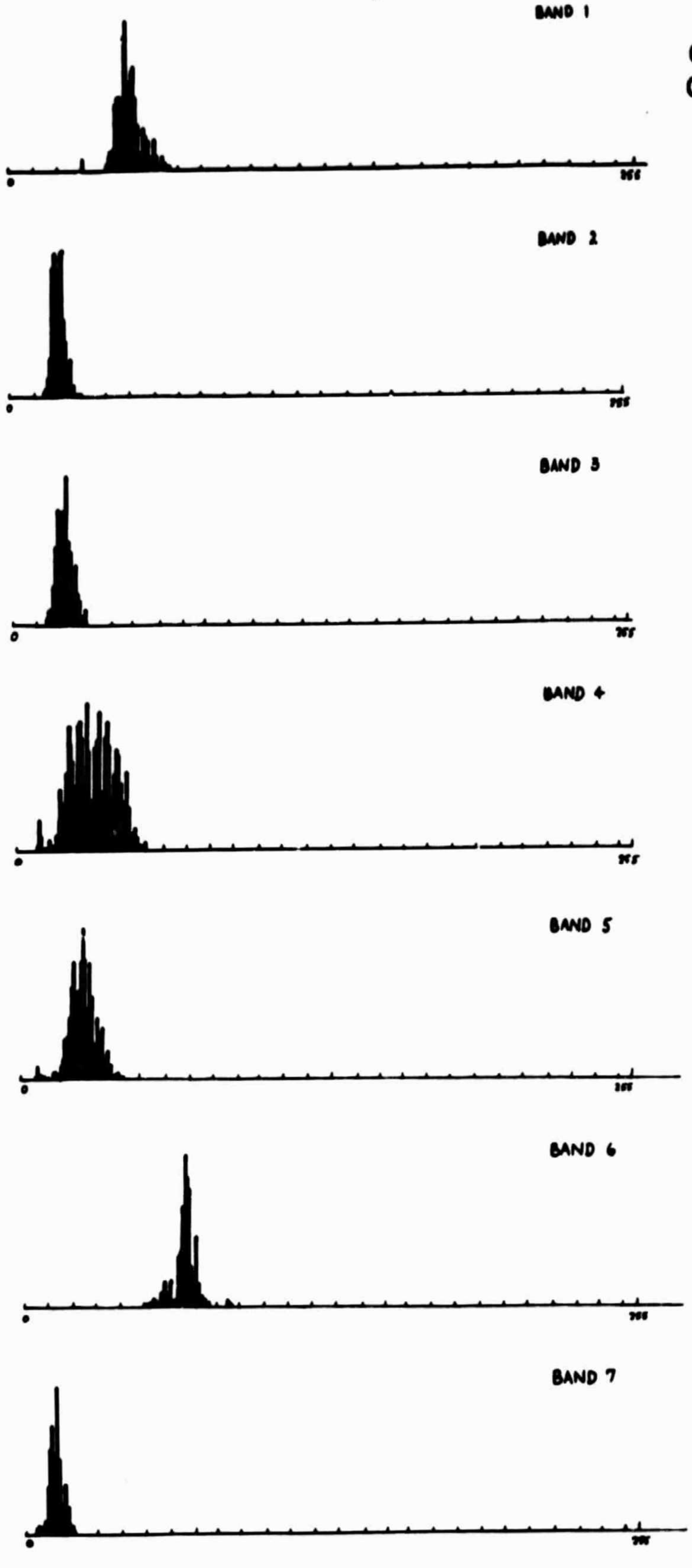

Figure 4 HISTOGRAMS FOR EACH SPECTRAL BAND FOR LONDON U.K. SCENE

NB BAND 6 :- THERMAL BAND

LONDON SCENE FEBRUARY 1983

BAND	SD OF SPECTRAL RESPONSE OF DETECTOR ARRAY	SD OF MEAN DETECTOR-TO-DETECTOR SPECTRAL RESPONSE
1	7.53	0.448
2	3.17	0.295
3	3.17	0.315
4	9.29	0.434
5	6.53	0.277
6	5.72	0.682
7	3.42	0.233

Note that Band 6 is the thermal Band

Figure 4 continued

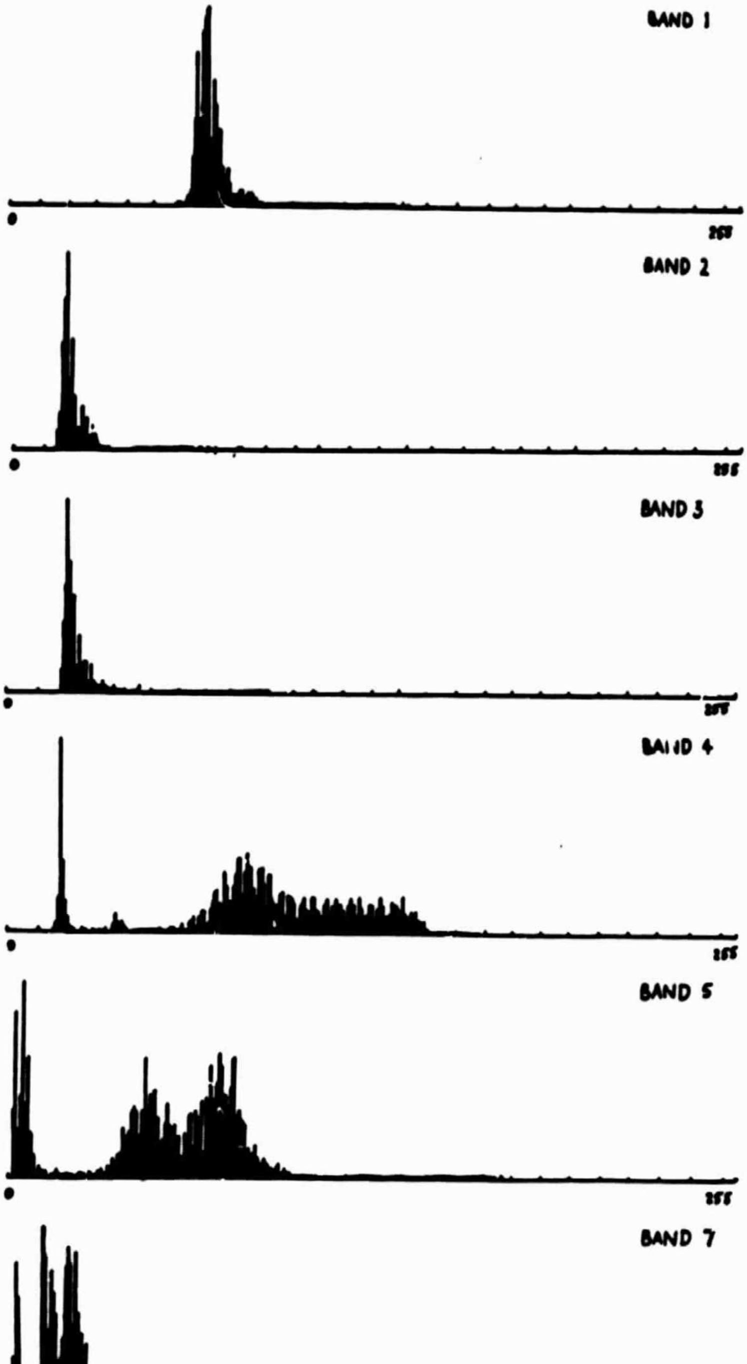

Figure 5 HISTOGRAMS FOR EACH SPECTRAL BAND FOR ARKANSAS SCENE

ARKANSAS SCENE AUGUST 1982

BAND	SD OF SPECTRAL RESPONSE OF DETECTOR ARRAY	SD OF MEAN DETECTOR-TO-DETECTOR SPECTRAL RESPONSE
1	[illegible]59	0.608
2	4.277	0.416
3	6.001	0.337
4	35.555	1.171
5	28.434	0.612
7	10.391	0.398

Note that SD for Band 5 is calculated without response from detector number 4 which was functioning incorrectly

Figure 5 continued.

The means and standard deviations for each of the detectors are shown in table 1 and plotted in figure 6. The corresponding values for the Arkansas sub-scene are given in table 2 and figure 7. Clearly the overall trend of the mean are very similar. Explanation of the deviations, and of the differences between in terms of standard deviation must await a comparison with a whole scene derived from the NASA/GSFC system.

The bands of the scene were all found to be misregistered in the x direction, and the thermal data was also misregistered in the y direction. The differences were up to 70 pixels in size. Fortunately a simple lateral shift resulted in images with satisfactory registration. Replication of the thermal infrared pixels has been done in rather peculiar way resulting in 'broken' pixels (figure 8).

LONDON U.K. SCENE FEBRUARY 1983

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BAND 1	DIGITAL COUNTS	
DETECTOR	X	SD
16	51.32	7.56
15	51.11	7.52
14	50.80	7.44
13	51.22	7.54
12	50.47	7.43
11	51.13	7.49
10	50.35	7.39
9	50.83	7.49
8	50.12	7.39
7	50.82	7.50
6	51.01	7.49
5	51.37	7.63
4	51.57	7.58
3	51.07	7.55
2	51.45	7.53
1	51.77	7.68
ALL	51.03	7.53

BAND 2	DIGITAL COUNTS	
DETECTOR	X	SD
16	20.63	3.21
15	20.45	3.15
14	20.42	3.15
13	19,96	3.08
12	20.12	3.10
11	20.08	3.11
10	20.25	3.13
9	20.22	3.13
8	20.21	3.13
7	20.64	3.20
6	20.67	3.22
5	20.48	3.11
4	20.29	3.14
3	20.34	3.27
2	21.12	3.25
1	20.03	3.10
ALL	20.36	3.17

Table 1 Means and standard deviations for each detector.

LONDON U.K. SCENE FEBRUARY 1983

BAND 3	DIGITAL COUNTS	
DETECTOR	X	SD
16	20.73	3.74
15	20.83	3.69
14	20.59	3.69
13	20.71	3.68
12	20.26	3.65
11	20.62	3.65
10	20.63	3.68
9	20.51	3.67
8	20.55	3.66
7	20.83	3.71
6	20.76	3.73
5	20.49	3.72
4	20.86	3.71
3	20.72	3.71
2	21.74	3.84
1	20.55	3.69
ALL	20.69	3.71

BAND 4	DIGITAL COUNTS	
DETECTOR	X	SD
16	30.64	9.44
15	31.26	9.20
14	31.53	9.34
13	31.25	9.29
12	31.00	9.11
11	32.35	9.56
10	31.23	9.19
9	31.28	9.25
8	31.24	9.25
7	31.55	9.32
6	31.01	9.23
5	31.08	9.30
4	31.81	9.39
3	31.12	9.30
2	32.14	9.38
1	31.27	9.21
ALL	31.38	9.29

Table 1 Continued.

LONDON U.K. SCENE FEBRUARY 1983

BAND 5	DIGITAL COUNTS	
DETECTOR	X	SD
16	25.53	6.53
15	25.84	6.53
14	25.95	6.58
13	26.25	6.63
12	26.22	6.65
11	25.43	6.39
10	25.78	6.50
9	26.14	6.50
8	26.03	6.72
7	25.80	6.62
6	25.29	6.44
5	25.57	6.45
4	25.87	6.21
3	25.67	6.49
2	25.81	6.55
1	26.01	6.61
ALL	25.82	6.57

BAND 7	DIGITAL COUNTS	
DETECTOR	X	SD
16	12.26	3.30
15	12.63	3.41
14	12.41	3.30
13	12.77	3.41
12	12.60	3.37
11	12.56	3.35
10	12.62	3.38
9	12.51	3.25
8	12.77	3.89
7	12.73	3.35
6	12.50	3.34
5	12.75	3.42
4	12.81	3.39
3	12.75	3.44
2	13.30	3.50
1	12.89	3.45
ALL	12.68	3.42

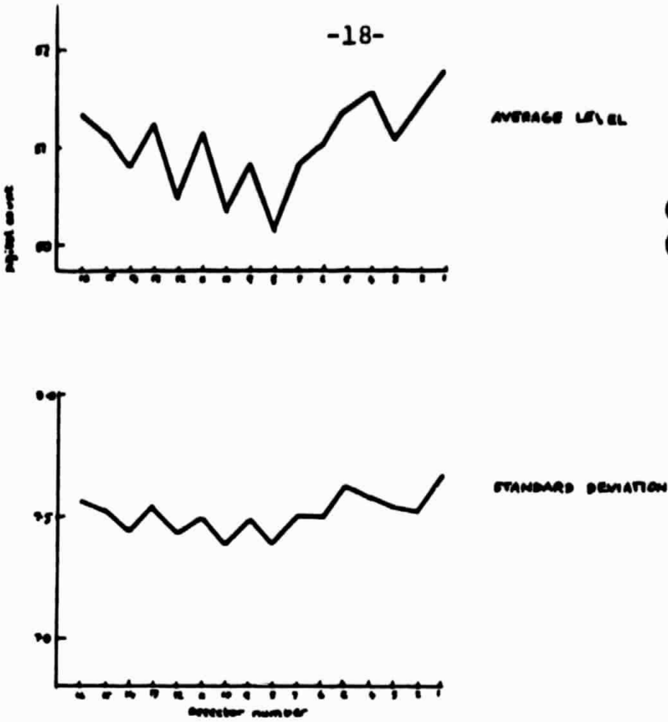
Table 1 Continued.

LONDON U.K. SCENE FEBRUARY 1983

BAND 6	DIGITAL COUNTS	
DETECTOR	X	SD
16	66.58	5.67
15	66.58	5.67
14	66.58	5.67
13	66.58	5.67
12	67.75	5.83
11	67.75	5.83
10	67.72	5.80
9	67.72	5.80
8	66.97	5.52
7	66.97	5.52
6	66.97	5.52
5	66.97	5.52
4	68.28	5.73
3	68.28	5.73
2	68.28	5.73
1	68.28	5.73
ALL	67.39	5.72

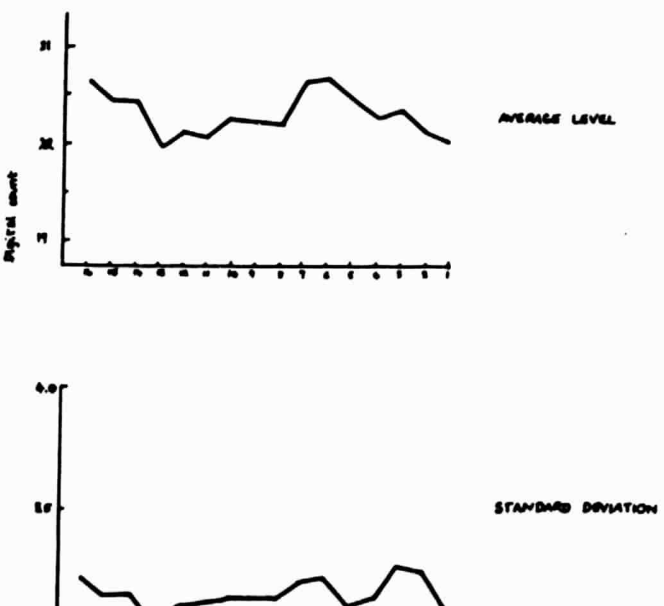
NB Thermal band

Table 1 continued.



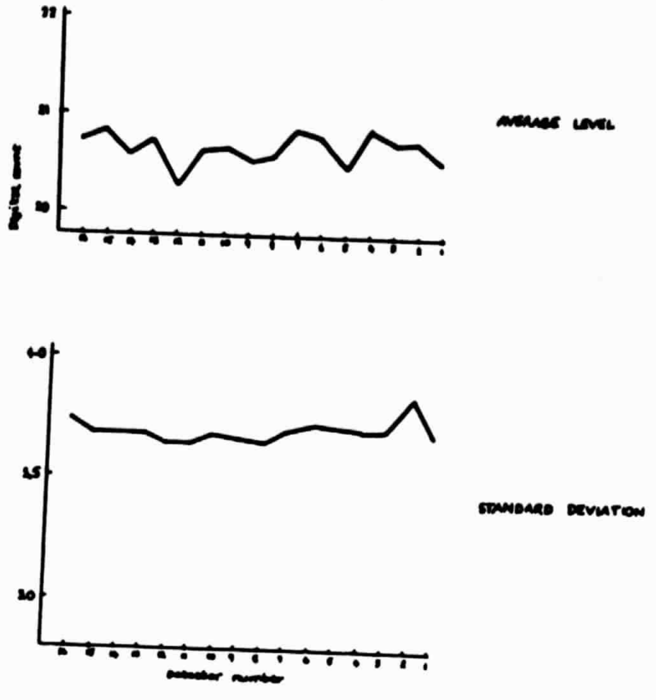
SPECTRAL RESPONSE FOR BAND 1

LONDON U.K. SCENE, FEBRUARY 1983

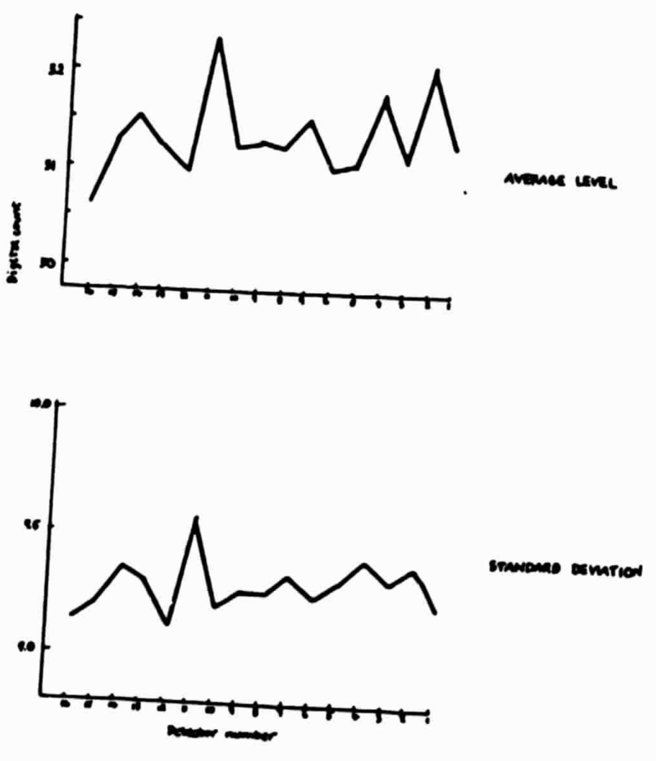


SPECTRAL RESPONSE FOR BAND 2 LONDON U.K. SCENE FEBRUARY 1983

Figure 6 Spectral response of the 16 detectors for each band for the UK Thematic Mapper scene.

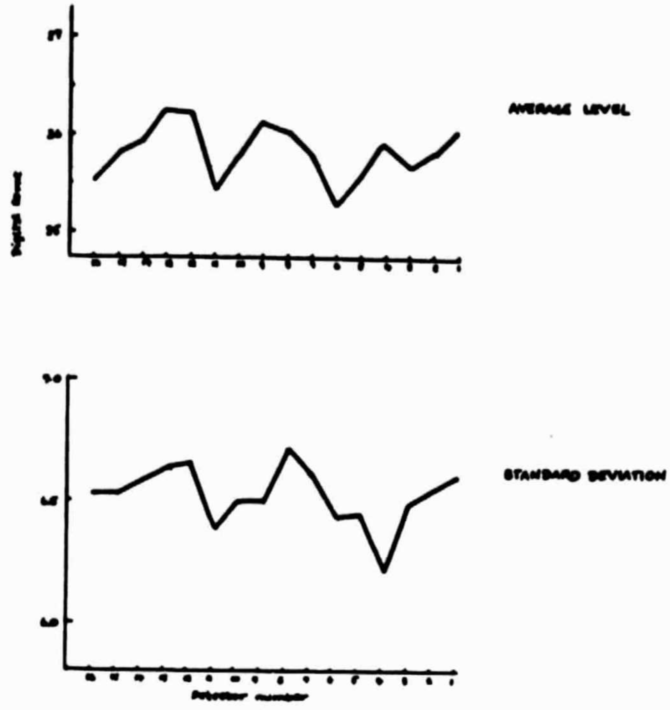


SPECTRAL RESPONSE FOR BAND 3 LONDON U.K. SCENE FEBRUARY 1983

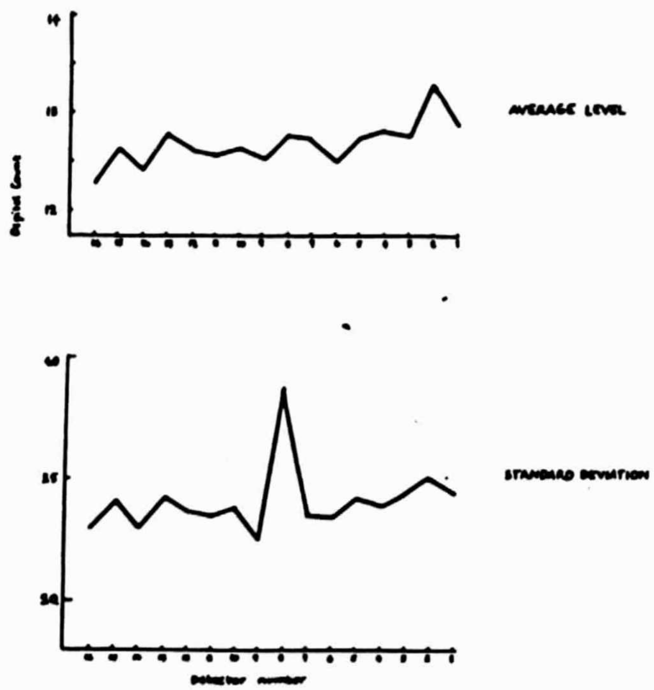


SPECTRAL RESPONSE FOR BAND 4 LONDON U.K. SCENE FEBRUARY 1983

Figure 6 continued.

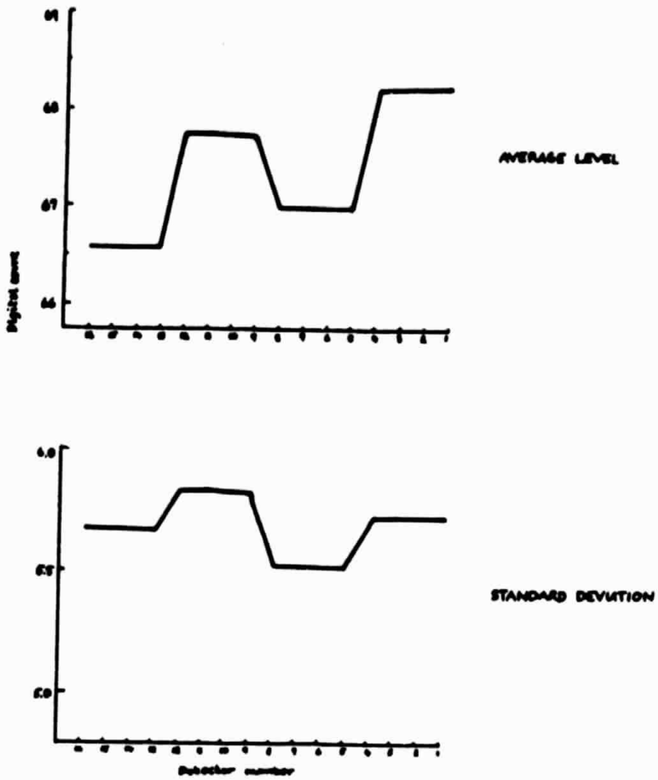


SPECTRAL RESPONSE FOR BAND 5 LONDON U.K. SCENE FEBRUARY 1983



SPECTRAL RESPONSE FOR BAND 7 LONDON ,U.K SCENE FEBRUARY 1983

Figure 6 continued.



SPECTRAL RESPONSE FOR BAND 6 LONDON U.K. SCENE FEBRUARY 1983

(THERMAL BAND)

Figure 6 continued.

ARKANSAS SCENE AUGUST 1982 (B DATA)

BAND 1	DIGITAL COUNTS	
DETECTOR	X	SD
16	71.192	5.461
15	70.690	5.460
14	70.494	5.337
13	71.343	5.435
12	69.895	5.315
11	71.014	5.583
10	69.807	5.486
9	70.521	5.453
8	69.421	5.298
7	70.627	5.257
6	70.556	5.343
5	70.858	5.634
4	71.395	5.556
3	70.695	5.522
2	71.134	5.468
1	71.636	5.598
ALL	70.948	1.159

Table 2 Means and standard deviations for B data from the Arkansas scene. (Calulations are for a single 512 x 512 subscene).

ARKANSAS SCENE AUGUST 1982 (B DATA)

BAND 2	DIGITAL COUNTS	
DETECTOR	X	SD
16	29.064	4.257
15	28.559	4.188
14	28.717	4.192
13	28.014	4.044
12	28.200	4.039
11	28.182	4.156
10	28.440	4.195
9	28.341	4.154
8	28.361	4.104
7	28.881	4.103
6	29.005	4.182
5	28.812	3.584
4	28.442	4.187
3	28.670	4.117
2	29.616	4.360
1	28.162	4.147
ALL	28.586	4.277

Table 2 continued.

ARKANSAS SCENE AUGUST 1982 (B DATA)

BAND 3	DIGITAL COUNTS	
DETECTOR	X	SD
16	24.124	5.958
15	24.129	5.865
14	23.899	5.948
13	23.947	5.955
12	23.459	5.862
11	23.859	5.982
10	23.828	6.079
9	23.611	5.876
8	23.757	5.839
7	24.089	5.882
6	24.065	5.910
5	23.702	5.938
4	24.213	6.012
3	24.072	6.001
2	24.972	6.147
1	23.864	5.888
ALL	23.978	6.001

Table 2 continued.

ARKANSAS SCENE AUGUST 1982 (B DATA)

BAND 4	DIGITAL COUNTS	
DETECTOR	X	SD
16	86.534	36.397
15	87.512	36.714
14	88.713	37.300
13	87.568	36.804
12	87.080	36.216
11	91.250	37.719
10	87.942	36.401
9	87.961	36.451
8	88.239	36.313
7	88.808	36.445
6	87.787	36.026
5	87.850	36.197
4	89.587	36.784
3	87.711	36.339
2	89.779	36.762
1	87.381	36.543
ALL	89.039	35.555

Table 2 continued.

ARKANSAS SCENE AUGUST 1982 (B DATA)

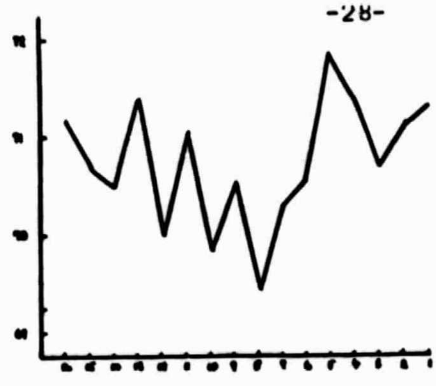
BAND 5	DIGITAL COUNTS	
DETECTOR	X	SD
16	56.292	26.629
15	57.152	26.702
14	57.349	26.841
13	58.197	27.137
12	58.093	27.014
11	56.269	25.933
10	57.133	26.366
9	57.730	26.430
8	57.827	26.456
7	57.450	26.130
6	56.246	25.619
5	57.179	25.958
4	2.874	0.604
3	57.349	26.481
2	57.470	26.556
1	57.499	27.096
ALL	54.441	28.435

Table 2 continued.

ARKANSAS SCENE AUGUST 1982 (B DATA)

BAND 7	DIGITAL COUNTS	
DETECTOR	X	SD
16	18.779	10.164
15	19.297	10.183
14	19.028	10.188
13	19.595	10.400
12	19.292	10.347
11	19.152	10.152
10	19.349	10.380
9	19.038	10.026
8	19.433	10.497
7	19.568	10.163
6	19.263	10.152
5	19.792	10.567
4	19.887	10.715
3	19.807	10.854
2	20.380	10.956
1	19.706	10.602
ALL	19.632	10.391

Table 2 continued.



AVERAGE LEVEL

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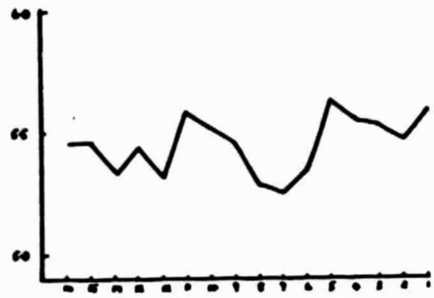
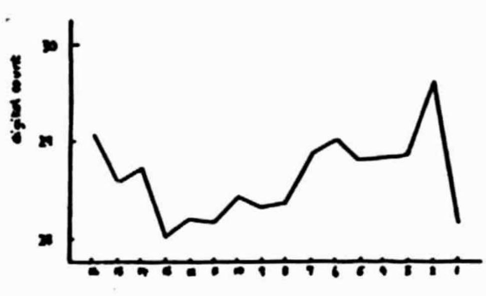


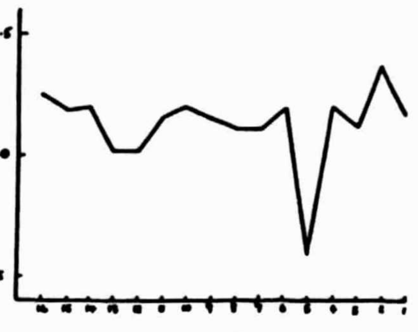
STANDARD DEVIATION

SPECTRAL RESPONSE FOR BAND 1 (B DATA)

ARKANSAS SCENE AUGUST 1982



AVERAGE LEVEL



STANDARD DEVIATION

SPECTRAL RESPONSE FOR BAND 2 (B DATA)

ARKANSAS SCENE AUGUST 1982

Figure 7 Spectral response of the 16 detectors for each band. Arkansas subscene (B data).

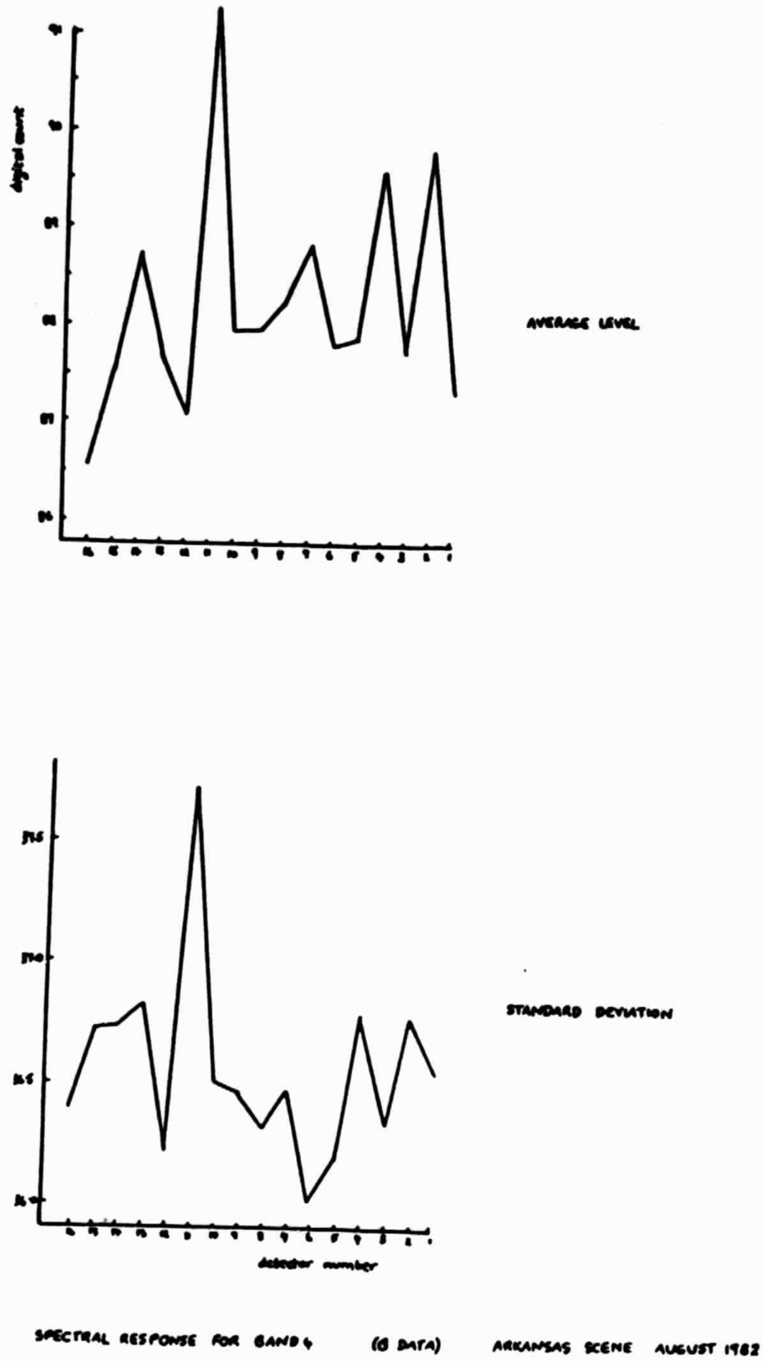
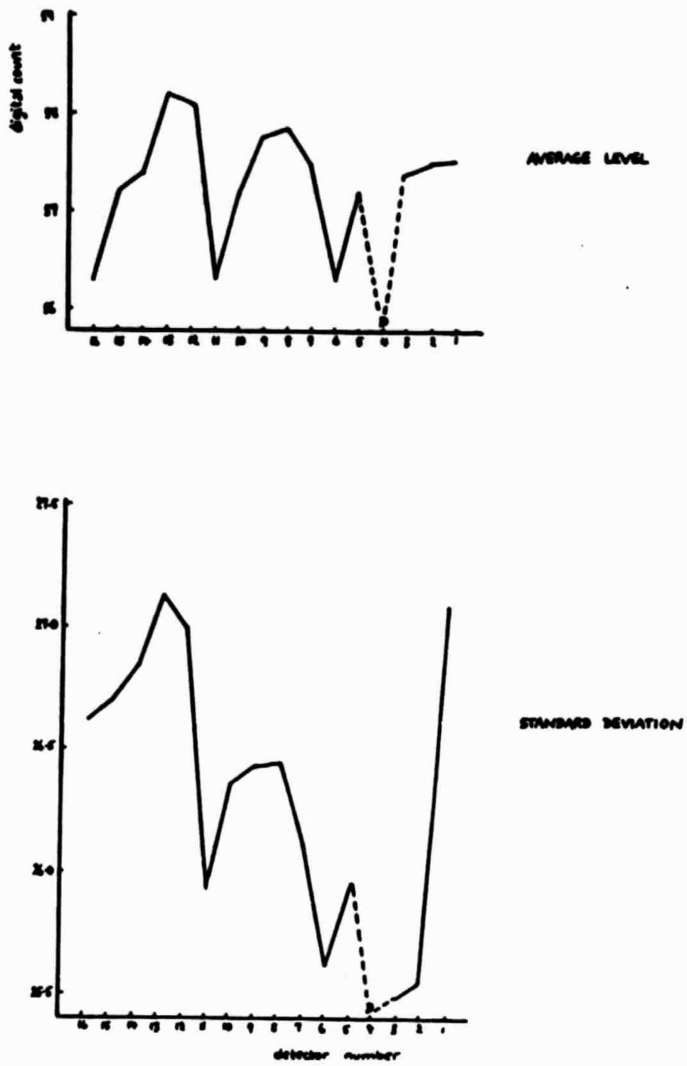


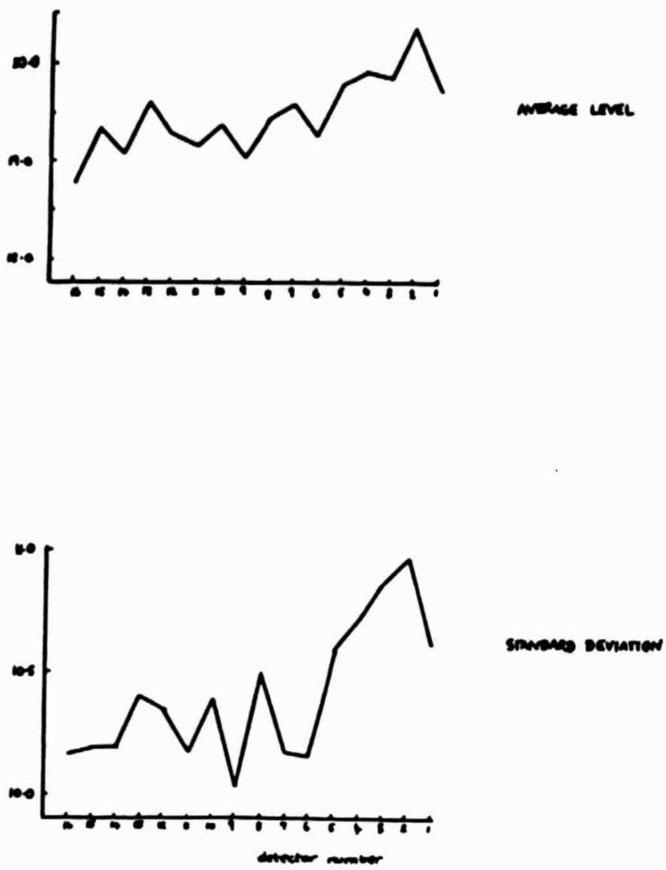
Figure 7 continued.



SPECTRAL RESPONSE FOR BAND 5 (B DATA)

ARKANSAS SCENE AUGUST 1982

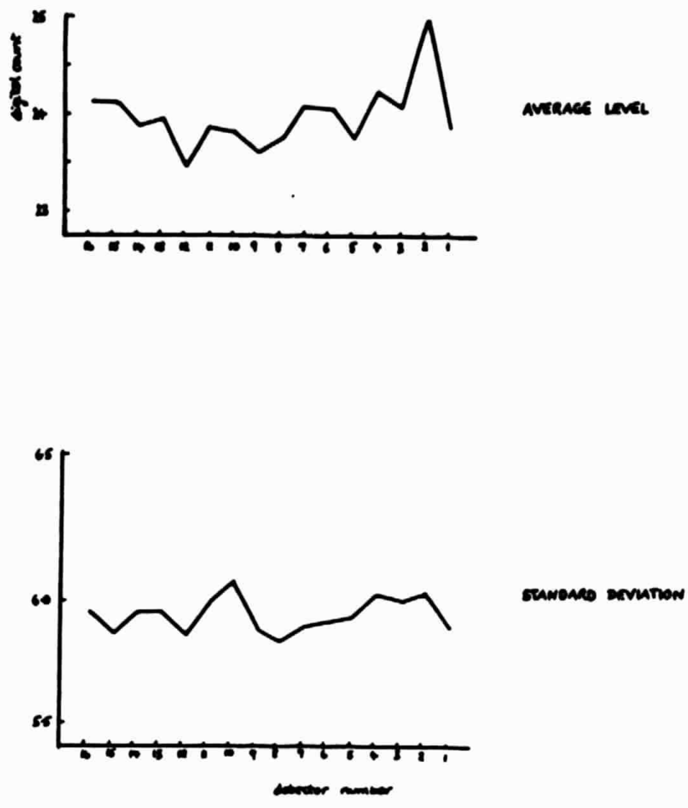
Figure 7 continued.



SPECTRAL RESPONSE FOR BAND 7 (B DATA)

ARKANSAS SCENE AUGUST 1982

Figure 7 continued.



SPECTRAL RESPONSE FOR BAND 3 (B DATA)

ARKANSAS SCENE AUGUST 1972

Figure 7 continued.

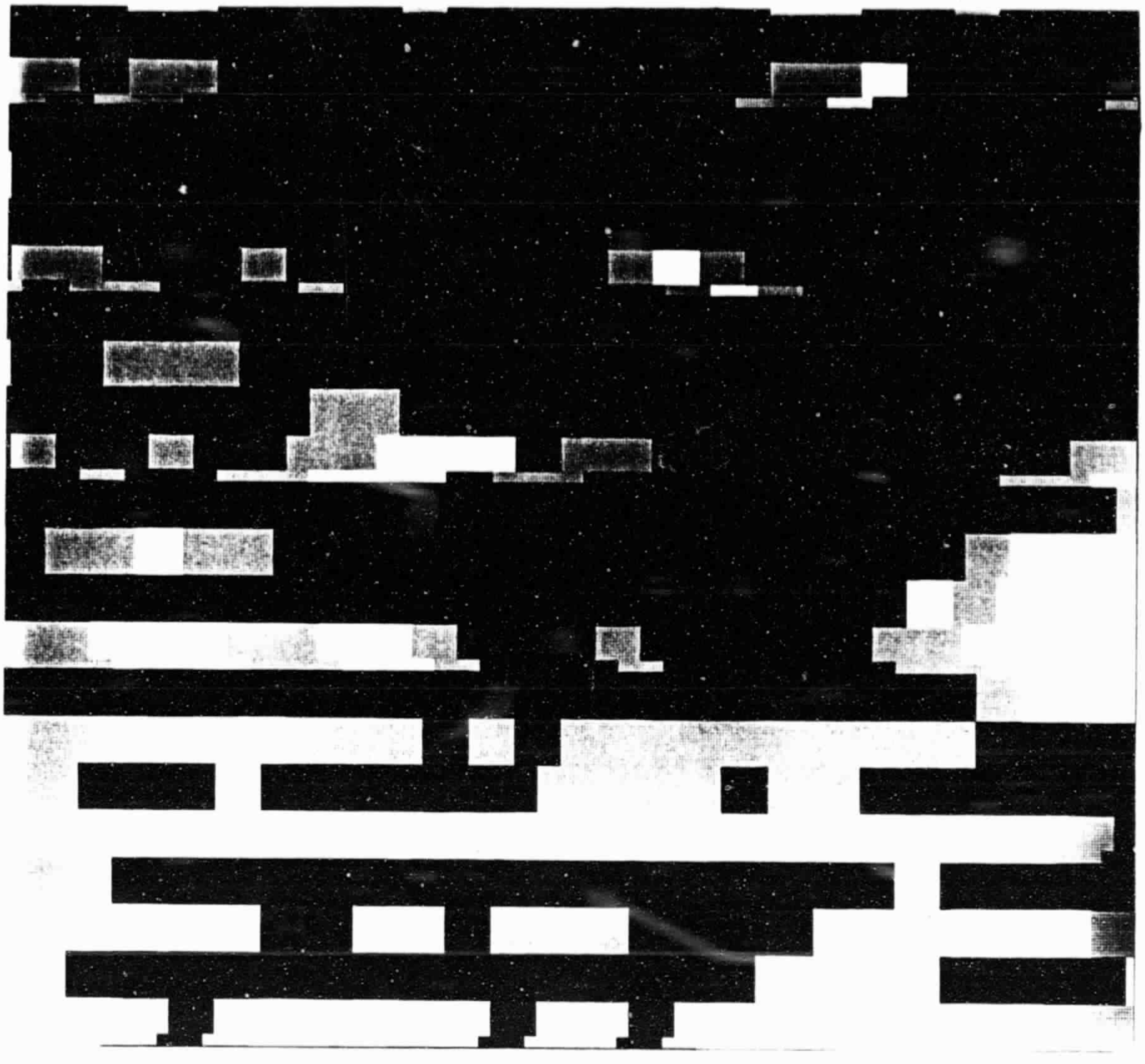


Figure 8 'Broken' band 6 (thermal) pixels from the UK scene.

Results of classification experiments.

Various experiments have been performed on the utility of the Thematic Mapper data for land cover classsifcation. It needs to be pointed out that a February scene is far from optimal for land cover classification because of the limited spectral contrast between some of the land cover categories at this time and because the low sun elevation introduces significant terrain shadow effects even in an area with low relief. Thus the classification accuracies should not be taken as indicative of the performance of the Thematic Mapper under more appropriate conditions. The results are nevertheless interesting because of the trends that are indicated and the problems that have been encountered.

Firstly a divergence analysis was performed which indicates the inherent separability of the classes on the basis of differences between the variance-covariance matrices and mean vectors of the different classes. Details of the procedure are described in Swain and Davis,(1978).[*] Both the divergence and transformed divergence results are given in Table 3. The latter is an asymptotic version of the former to allow for the finite limit of accuracy of 100%.

These results show the best two of the six bands (table 3a and 3b), the best three of the six bands (table 3c and 3d) and the best four of the six bands (table 3e and 3f). These are in broad agreement with results reported in our first progress report for the Arkansas scene. They stress the over-riding importance of the near infrared band and red band and the middle IR (band 5) band for land cover discrimination. They also show that for individual cover categories, all the bands appear to have separate discriminatory value. The thermal band was not considered beca use of the problems outlined above.

Swain, P and Davis, S. Remote Sensing: the quantitative approach. McGraw-Hill, New York, 1978.

	BANDS					
	1	2	3	4	5	7
WOODA (DECID)	-	-	-	X	X	-
WOODB (CONIF)	-	-	X	X	-	-
AGRICULTURE	-	X	-	X	-	-
CBD	-	-	-	X	X	-
RESIDENTIAL	-	-	-	X	X	-
INDUSTRY	-	-	X	X	-	-
WATER	-	-	-	X	X	-
ALL CLASSES	-	-	-	X	X	-

a) DIVERGENCE FOR THE BEST 2 OUT OF 6 CHANNELS

	BANDS					
	1	2	3	4	5	7
WOODA (DECID)	-	-	X	-	X	-
WOODB (CONIF)	-	-	-	X	X	-
AGRICULTURE	-	-	X	X	-	-
CBD	-	-	X	X	-	-
RESIDENTIAL	-	-	X	X	-	-
INDUSTRY	-	-	X	X	-	-
WATER	-	-	-	X	X	-
ALL CLASSES	-	-	X	X	-	-

b) TRANSFORMED DIVERGENCE FOR THE BEST 2 OUT OF 6 CHANNELS

Table 3 Results of divergence analysis for the Reading subscene.

	BANDS 1	2	3	4	5	7
WOODA (DECID)	-	-	X	X	X	-
WOODB (CONIF)	-	-	X	X	X	-
AGRICULTURE	-	X	-	X	X	-
CBD	-	-	X	X	X	-
RESIDENTIAL	-	X	-	X	X	-
INDUSTRY	-	-	X	X	X	-
WATER	-	X	-	X	X	-
ALL CLASSES	-	x	-	X	X	-

c) DIVERGENCE FOR THE BEST 3 OUT OF 6 CHANNELS

	BANDS 1	2	3	4	5	7
WOODA (DECID)	X	-	-	X	X	-
WOODB (CONIF)	X	-	-	X	X	-
AGRICULTURE	-	-	X	X	X	-
CBD	-	-	X	X	X	-
RESIDENTIAL	-	-	X	X	X	-
INDUSTRY	-	X	-	X	-	X
WATER	-	-	-	X	X	X
ALL CLASSES	-	-	X	X	X	-

d) TRANSFORMED DIVERGENCE FOR THE BEST 3 OUT OF 6 CHANNELS

Table 3 continued.

	BANDS					
	1	2	3	4	5	7
WOODA (DECID)	-	X	X	X	X	-
WOODB (CONIF)	X	-	X	X	X	-
AGRICULTURE	-	X	X	X	X	-
CBD	-	X	X	X	X	-
RESIDENTIAL	X	X	-	X	X	-
INDUSTRY	-	X	X	X	X	-
WATER	-	X	X	X	X	-
ALL CLASSES	-	X	X	X	X	-

e) DIVERGENCE FOR THE BEST 4 OUT OF 6 CHANNELS

	BANDS					
	1	2	3	4	5	7
WOODA (DECID)	X	X	-	X	X	-
WOODB (CONIF)	X	X	-	X	X	-
AGRICULTURE	-	-	X	X	X	X
CBD	-	X	X	X	X	-
RESIDENTIAL	X	-	X	X	X	-
INDUSTRY	-	X	X	X	-	X
WATER	-	-	X	X	X	X
ALL CLASSES	X	-	X	X	X	-

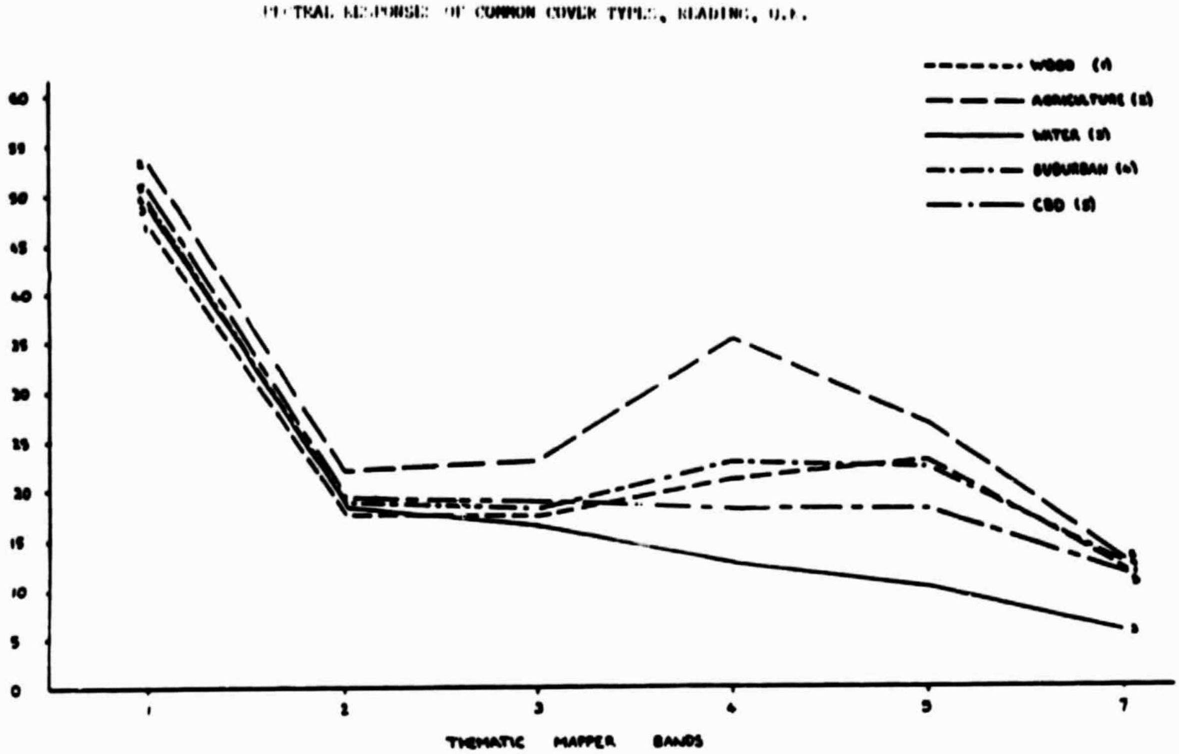
f) TRANSFORMED DIVERGENCE FOR THE BEST 4 OUT OF 6 CHANNELS

Table 3 Continued.

The importance of bands 3, 4 and 5 in giving a distinctive mutlispectral response can also be gauged visually by examination of figure 9.

The results of classification experiments in deriving actual contingency tables can be seen in Table 4. The classifier used was a minimum distance to the mean classifier using a city block distance measure. It is unfortunate that such a simple classifier had to be used, but problems in reprogramming the I^2S to deal with seven band data, have prevented use of a maximim likelihood classifier.

Table 4a and 4b show the results of applying the classifier for a set of training sites for 5 broad land cover categories. In the first set the separate training sites were retained and the classes combined after classification. Although the overall accuracy is approximately the same, the accuracy of individual catgeories varies substantially. An attempt to improve the classification accuracy by reclassifying the data on the basis of the frequency of classes in a 3 by 3 window was made and the results are shown in table 4c. Once again the overall success rate has changed little but it is interesting to note the effects on individual cover categories. Those where accuracies are low tend to be depressed even more by the preponderance of incorrect classes around them, whereas those with relatively high accuracies are unaffected or improved. Part of the reason for the low classification accuracies stems from the amount of internal variability within individual categories especially the suburban residential one. With this in mind a smoothing 5 x 5 filter was passed over the data, each cell containing a value of 0.04. The pixel size of 30 meters was kept the same and the results in table 4d obtained, which are rather better than those previously obtained. Visual inspection of the images suggests these land cover categories often have very distince textures, so we are currently deriving a number of texture images to act as additional features for land cover discrimination.



	WOOD	AGRIC	WATER	SUB	CBD
B1	47.107	53.444	49.083	49.269	50.443
B2	17.752	22.002	18.361	18.840	19.013
B3	17.537	22.960	16.611	18.830	19.252
B4	21.134	35.272	12.406	23.758	17.890
B5	23.077	26.933	9.933	22.533	17.966
B7	11.978	12.948	5.750	12.406	11.726

Figure 9 Characteristic spectral response curves derived from the February 1983 UK scene.

CONTINGENCY TABLES

CLASS

	1	2	3	4	5	6	7	8	9	10	11	12
1	6	0	6	0	0	9	3	11	0	9	9	27
2	7	0	8	1	0	2	0	16	0	5	17	21
3	5	0	13	0	0	3	0	3	0	3	2	35
4	0	0	1	39	0	7	0	0	0	0	0	6
5	21	0	19	11	0	17	0	0	0	18	4	29
6	1	0	3	25	0	61	0	0	0	0	0	31
7	0	0	0	0	0	0	24	0	0	0	0	0
8	4	0	2	2	0	0	2	93	0	9	35	7
9	7	0	6	0	0	1	13	64	0	15	35	10
10	12	0	10	4	0	0	0	11	0	28	39	16
11	6	0	3	0	0	0	0	25	0	8	24	1
12	7	0	15	11	0	14	0	2	0	12	9	38

CLASS

	WOOD	AGRIC	WATER	CBD	SUB	
WOOD	45	15	3	30	139	(19.4%)
AGRIC	45	160	0	0	84	(55.4%)
WATER	0	0	24	0	0	(100%)
CBD	19	3	15	157	111	(51.5%)
SUB	53	29	0	38	175	(59.3%)

OVERALL PERCENTAGE CLASSIFICATION ACCURACY = 57.12%

a) Use of separate training sites for classification.

Table 4 Results of minimum distance to the mean classification

CONTINGENCY TABLE USING COMBINED CLASSES

	WOOD	AGRIC	WATER	CBD	SUB	
WOOD	45	101	3	62	17	(19.7%)
AGRIC	46	238	0	4	18	(77.78%)
WATER	0	0	24	0	0	(100%)
CBD	21	20	16	229	25	(73.6%)
SUB	55	85	0	109	47	(15.9%)

OVERALL PERCENTAGE CLASSIFICATION ACCURACY = 57.41%

b) Statistics derived for combined training sites.

CONTINGENCY TABLE AFTER RECLASSIFICATION

	WOOD	AGRIC	WATER	CBD	SUB	
WOOD	29	121	0	67	5	(13.1%)
AGRIC	50	232	0	0	12	(78.9%)
WATER	0	0	24	0	0	(100%)
CBD	1	13	4	274	1	(93.5%)
SUB	44	92	0	128	28	(9.6%)

OVERALL PERCENTAGE CLASSIFICATION ACCURACY =59.02%)

c) Results obtained by reclassifying (b).

CONTINGENCY TABLE AFTER APPLYING A 5X5 SMOOTHING FILTER

	WOOD	AGRIC	WATER	CBD	SUB	
WOOD	120	50	0	19	44	(51.5%)
AGRIC	52	243	0	0	0	(82.4%)
WATER	0	0	23	1	0	(96.0%)
CBD	15	25	0	213	69	(66.1%)
SUB	145	47	0	23	80	(27.1%)

OVERALL PERCENTAGE CLASSIFICATION ACCURACY = 64.6%

d) Results of smoothing the original digital data.

After reclassification:

	WOOD	AGRIC	WATER	CBD	SUB	
WOOD	120	82	0	19	44	(49.6%)
AGRIC	54	241	0	0	0	(81.6%)
WATER	0	0	23	1	0	(96.0%)
CBD	16	0	0	215	94	(66.2%)
SUB	144	47	0	23	81	(26.6%)

OVERALL PERCENTAGE CLASSIFICATION ACCURACY = 64.1%

e) Results of reclassifying (d).

Table 4 continued.

These preliminary results indicate the inadequacy of simple perpoint classifiers and the need to develop contextual and textural measures if Thematic Mapper data are to be fully exploited. It is clear from visual analysis of the Thematic Mapper data that they are very much better for land cover discrimination than MSS data. A very large proportion of fields can be resolved for the UK. which augers well for crop discrimination, and the urban rural boundary has been found to be readily detectable at least by eye because of the characteristic high frequency variations typical of urban scenes. A major effort is clearly required however if the potential of the Thematic Mapper data is to be exploited fully, especially in the field of automated information extraction.

Publications

Townshend, J.R.G., Gayler, J.R., Hardy, J.R. Jackson, M.J. and Baker, J.R. 1983. Preliminary analysis of Landsat 4 Thematic Mapper products. Int. J. of Remote Sensing, 4, 817-828.

Townshend, J.R. and Jackson, M. 1983 Down to detail with the Thematic Mapper. Geographical Magazine, 55, 442-3.

Townshend, J.R.G. 1984. Agricultural land cover discrimination using Thematic Mapper spectral bands. International J. of Remote Sensing, 5 (in the press). (This paper largely contains an analysis of simulation data but also considers and displays the results of, a Prinipal Components analysis of Thematic Mapper images).

Hardy, J.R. 1983 Evaluation of Thematic Mapper of Landsat 4 for land use inventories. Ispra Course Lecture Notes for the course on Remote Sensing for Land Use Inventories, September 12th-30th 1983, 22 pp.

Problems

Our principal problem already referred to, is a lack of data for our test sites. Happily this has partly been corrected recently by the provision of data from ESRIN, though we only have radiometrically uncorrected data as yet. We look forward eagerly to receiving NASA data of our test sites following the launch of Landsat D'.

Our other major problem has been that of modifying software to cope with Thematic Mapper data. This has consumed many man months of effort especially with respect to the I^2S system at NERC Swindon. Hopefully this effort will diminish siginificantly during the remainder of the project.